JTX 30

United States Patent [19]

Stokes et al.

[11] 4,380,893

[45] Apr. 26, 1983

[54] COMPRESSOR BLEED AIR CONTROL APPARATUS AND METHOD

[75] Inventors: Richard F. Stokes, Phoenix; James D. Timm, Tempe; Stephen R. LaCroix, Scottsdale; Milton R. Adams, Tempe, all of Ariz.

[73] Assignee: The Garrett Corporation, Los Angeles, Calif.

[21] Appl. No.: 235,794

[22] Filed: Feb. 19, 1981

[51] Int. Cl.^{3} F04D 27/02

[52] U.S. Cl. 60/39.07; 415/27

[58] Field of Search 60/39.07, 39.29, 39.27; 415/27, 28; 417/405, 406

[56] References Cited

U.S. PATENT DOCUMENTS

1,052,172	2/1913	Rateau	415/27
1,154,959	9/1915	Banner	415/27
2,994,471	8/1961	Lewis et al.	417/406
3,047,210	7/1962	Best	415/27
3,362,626	1/1968	Schlirf	415/27
3,364,837	1/1968	Schooling .	
3,373,675	3/1968	Best .	
3,411,702	11/1968	Metot et al.	415/27
3,441,045	4/1969	Malone .	
3,706,270	12/1972	Furlong .	
3,728,955	4/1973	Ricaud .	
3,842,720	10/1974	Herr .	

FOREIGN PATENT DOCUMENTS

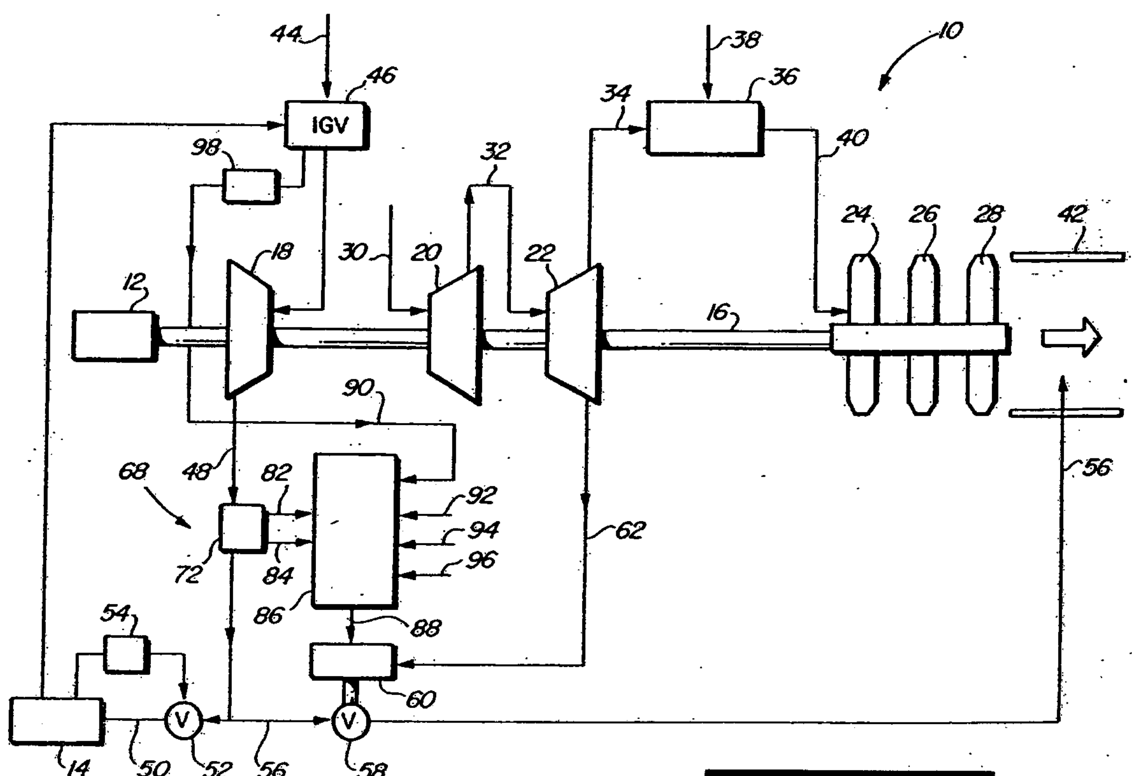
1021797	3/1966	United Kingdom	415/27

Primary Examiner—Louis J. Casaregola
Attorney, Agent, or Firm—J. Richard Konneker; Albert J. Miller

[57] ABSTRACT

A turbine engine accessory power unit has a compressor bleed air control system in which a surge bleed valve is proportionally and integrally controlled to maintain a constant minimum compressor bleed flow rate slightly above the compressor's surge flow rate. The system control parameter is automatically reset as a function of the position of the compressor's adjustable inlet guide vanes to assure optimum control system performance throughout the air delivery range of the compressor.

23 Claims, 6 Drawing Figures



REMAND
JTX 30

AS 198898

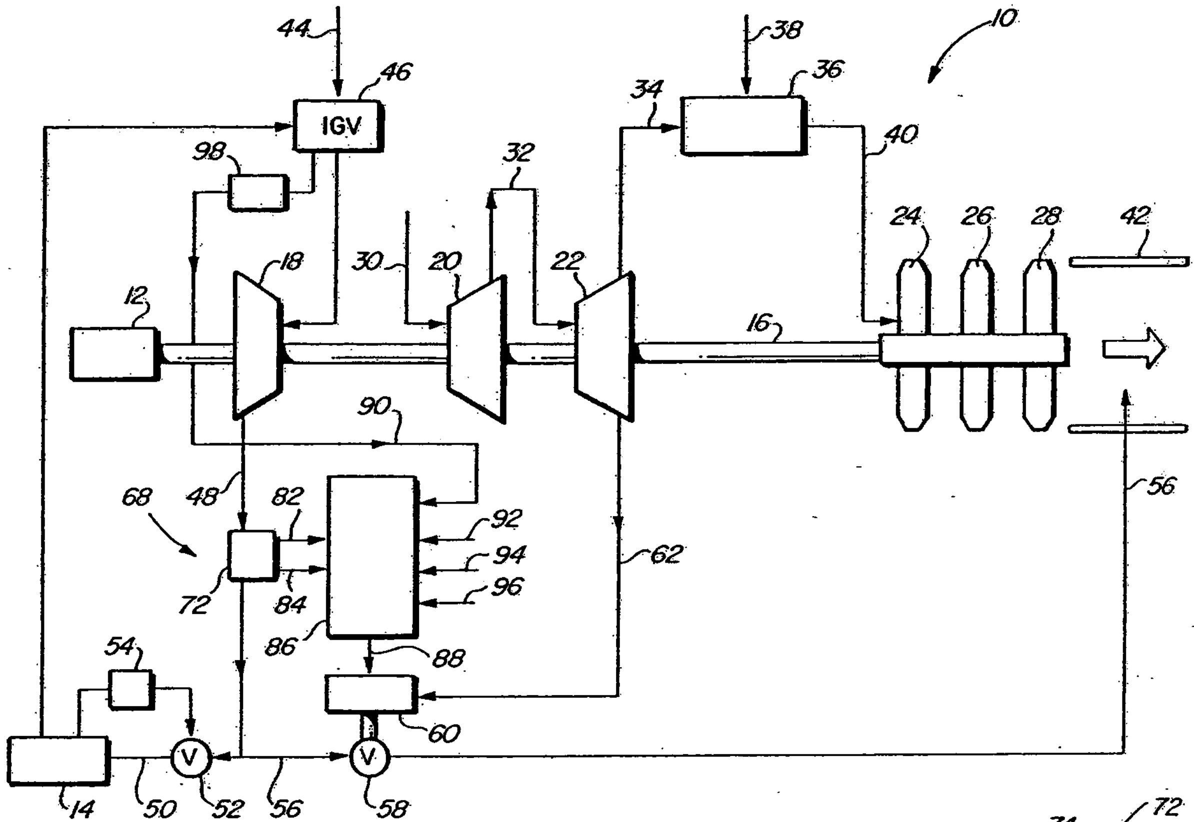


FIG. 1

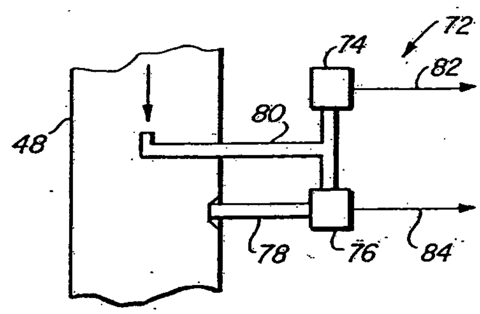


FIG. 3

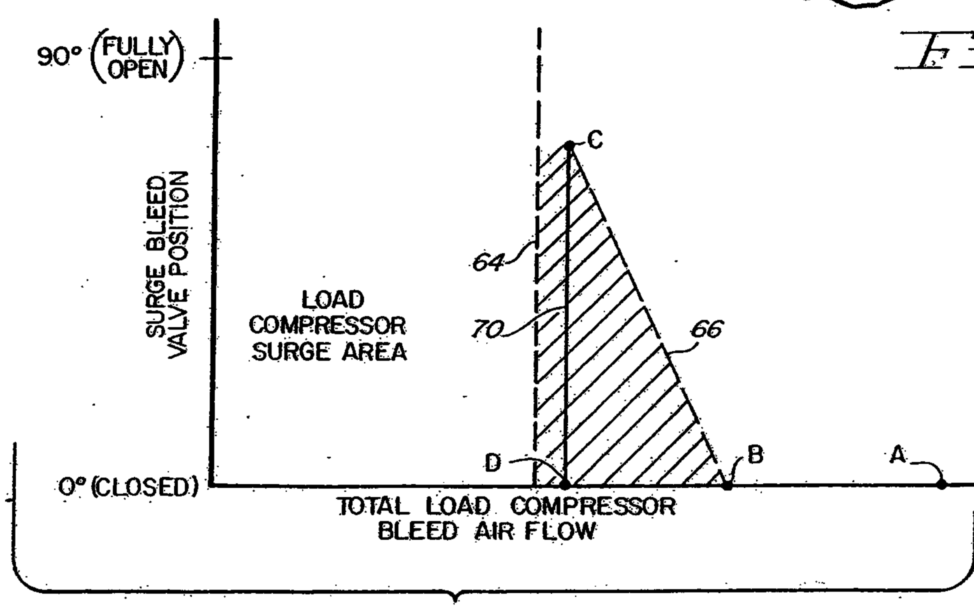


FIG. 2

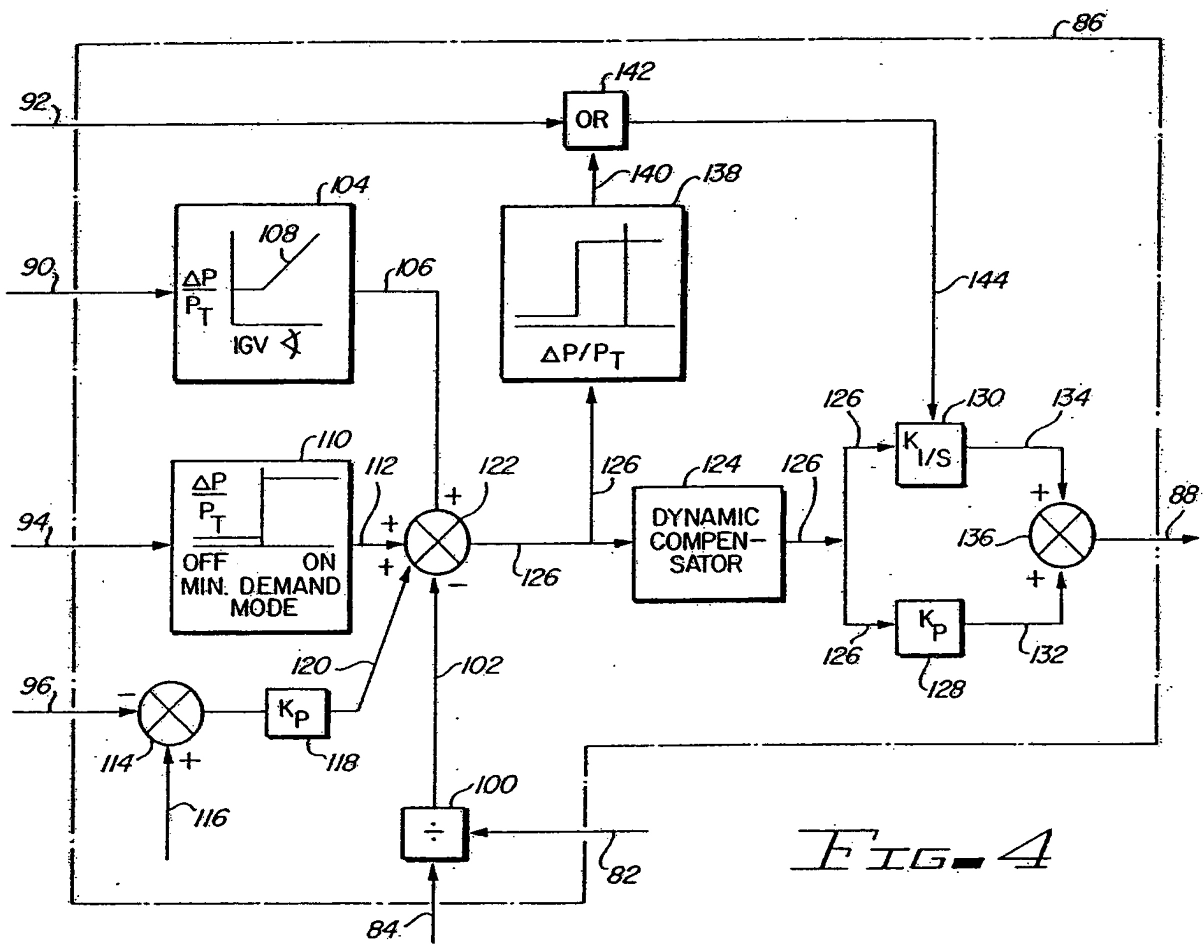


FIG. 4

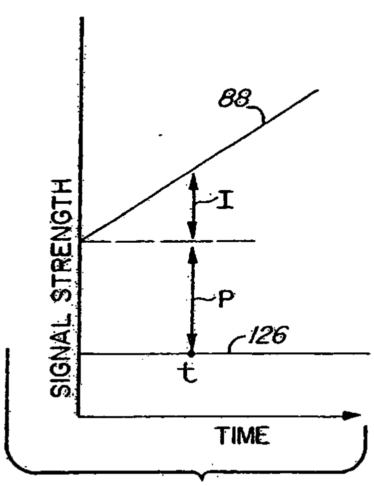


FIG. 5

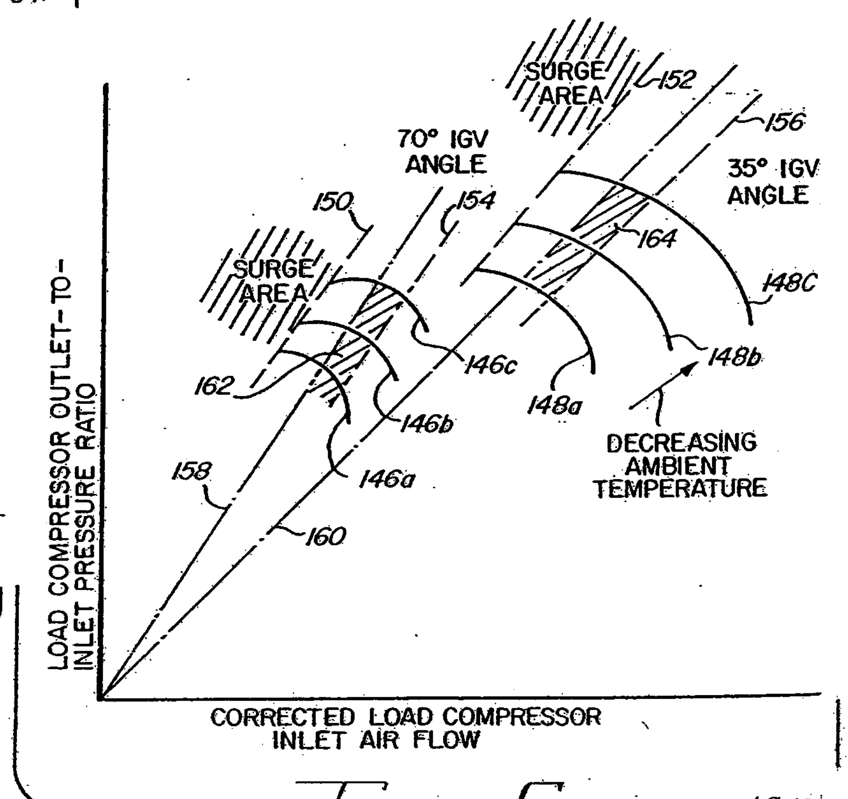


FIG. 6

AS 198900

COMPRESSOR BLEED AIR CONTROL APPARATUS AND METHOD

BACKGROUND OF THE INVENTION

The present invention relates generally to apparatus and methods for regulating the flow rate of gas discharged from a compressor, and more particularly to a novel bleed air control system adapted to assure a constant minimum discharge flow rate in a compressor used to power pneumatically-operated aircraft accessory system and the like.

In addition to their traditional propulsion functions, gas turbine engines are often used as accessory power units (APU's) to supply mechanical and/or pneumatic power to a wide variety of aircraft accessory devices and systems. Accessory system pneumatic power is typically provided by forcing bleed air from the APU compressor section through a main bleed duct to the accessory system's supply inlet via a branch supply duct connected to and defining a terminal portion of the main duct. In order to prevent surge of the APU compressor used to power the pneumatic accessory system, it is necessary to maintain a certain minimum flow rate through the main bleed duct.

However, the APU-supplied accessory system normally has a widely fluctuating compressed air requirement and is automatically controlled to correspondingly regulate the amount of bleed air it receives from the compressor by modulation of an accessory valve positioned in the branch supply duct.

To accommodate a decrease in accessory air demand, and maintain the compressor through flow above its surge level, a surge bleed duct is typically connected to the main bleed duct to provide an alternate outlet flow path for the compressor bleed air as flow through the branch supply duct is diminished by a closing of the accessory system valve. Flow through the surge bleed duct is regulated by modulating a surge bleed valve positioned therein.

Conventional bleed air control systems employ mechanical devices, such as diaphragm controllers, to proportionally operate the surge bleed valve in response to deviations in main duct flow rate from a desired value thereof. More specifically, as the main duct flow rate begins to deviate from a predetermined value, an error signal is generated and the control system responsively modulates the surge bleed valve to a degree directly proportional to the magnitude of the error signal.

Such conventional control of the surge bleed valve requires that the valve be initially opened at a total compressor bleed air level substantially higher than the minimum flow level (i.e., a flow level exceeding the surge level by a reasonable margin of safety) required to prevent surge of the compressor. The early surge valve opening, necessitated by the steady-state droop characteristics of proportional control which cause the surge valve operating line to be angled relative to the compressor surge line, results in a sizable amount of excess surge bleed air being dumped to atmosphere as the surge valve is moved toward its fully open position. This heretofore unavoidable excess surge bleed air causes increased APU fuel consumption, results in increased surge bleed noise, decreases total power available from the APU, and limits the maximum supply pressure available to the pneumatically-powered accessory system.

SUMMARY OF THE INVENTION

Accordingly, it is an object of the present invention to provide an improved compressor system, and a bleed air control system and methods therefor, which eliminates or minimizes the above-mentioned excess surge bleed air flow as well as other problems and disadvantages.

The present invention provides an electronic bleed air control system which senses a flow-related control parameter within the main compressor bleed duct and responsively generates an error signal indicative of the difference between the sensed value of the parameter and a desired value thereof. The error signal is converted to two signals, one of which is proportional to the error signal and the other of which represents the integral, as a function of time, of the error signal. These two control signals are used simultaneously to modulate the surge bleed valve.

This unique combination of integral and proportional control of the surge bleed valve yields a valve operating or control line which is essentially parallel to the compressor surge line, thus allowing the initial surge valve opening to be delayed until the compressor bleed flow rate is only slightly above its surge rate. Because of the greatly improved surge valve control characteristics afforded by the present invention, the only excess surge bleed air required is that needed to provide a reasonable safety margin above the surge flow rate, and is essentially constant for all positions of the surge valve.

In a preferred embodiment of the present invention, the electronic control system is used in conjunction with a gas turbine engine accessory power unit (APU) to supply compressed air to a pneumatically-operated accessory system having a variable air demand. The APU has a load compressor which is provided with adjustable inlet guide vanes. Connected to the compressor is a main bleed air duct having a branch supply duct interconnecting the main duct with the accessory system, and a surge bleed duct (and associated surge bleed valve) for dumping bleed air to atmosphere as the accessory system air demand diminishes.

In this preferred embodiment, the electronic control system comprises flow sensor means for sensing within the main bleed duct the value of the flow-related parameter $(P_t-P_s)/P_t$, P_t being the total pressure within the main duct, and P_s being the static pressure therein. Means are provided for comparing the sensed value of such parameter to a desired value thereof and responsively generating a error signal representing the difference between the sensed and desired parameter values. The error signal is transmitted in parallel to a proportional controller and an integral controller whose outputs are combined by a summing device to form the combined proportional-and-integral control signal which ultimately regulates the position of the surge bleed valve.

Additionally, means are provided for automatically resetting the desired value (or "set point") of the flow parameter as a function of the position of the load compressor inlet guide vanes. The use of the particular flow parameter $(P_t-P_s)/P_t$, coupled with the correlation of the set point value with the inlet guide vane position, uniquely provides for optimum control system performance, maintaining the surge valve control line essentially parallel to the compressor surge flow line despite

wide variations in compressor through flow and ambient temperatures.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic diagram of a gas turbine engine accessory power unit in which is incorporated a compressor bleed air control system embodying principles of the present invention;

FIG. 2 is a graph which comparatively depicts the surge bleed valve control characteristics of the control system of FIG. 1 and those of a conventional, proportional control system;

FIG. 3 is an enlarged, schematic illustration of the flow sensor portion of the control system of FIG. 1;

FIG. 4 is an enlarged schematic diagram showing the components of the electronic controller portion of the control system of FIG. 1;

FIG. 5 is a graph depicting the relationship between the electronic controller output signal and an error signal generated by the control system of FIG. 1; and

FIG. 6 is a graph illustrating the relationship between the control system flow parameter and the position of the load compressor inlet guide vanes of the accessory power unit.

DETAILED DESCRIPTION

A gas turbine engine accessory power unit (APU) 10 is schematically illustrated in FIG. 1 and constitutes a preferred embodiment of the present invention. Accessory power units such as APU 10 are typically used to provide mechanical power to a driven accessory such as a generator 12, and to simultaneously supply compressed air to an accessory system such as an aircraft environmental control system 14 or to other pneumatically-operated devices such as air turbine motors and the like.

APU 10 includes a power shaft 16 drivingly coupled at its left end (through a gearbox not shown in FIG. 1) to the generator 12. Fixedly mounted on shaft 16 for rotation therewith are, from left to right along its length, a centrifugal load compressor 18, first and second stage centrifugal power compressors 20, 22, and first, second, and third stage axial power turbines 24, 26, and 28, positioned at the right end of the shaft 16.

During operation of the APU, ambient air 30 is drawn into the inlet of the first stage power compressor 20, compressed, and then discharged through duct 32 into the inlet of the second stage power compressor 22 where it is further compressed. Compressor 22 discharges the further compressed air through a duct 34 into a combustor 36. The compressed air entering combustor 36 is mixed with fuel 38 also supplied to the combustor to form a fuel-air mixture which is continuously burned therein. Expanded gas 40 exiting the combustor is forced axially through the power turbines 24, 26, 28 to supply rotational power to the shaft 16 and is exhausted from the APU to atmosphere through a discharge passage 42 positioned immediately downstream of the power turbines.

The rotation of the shaft 16 drives the generator 12 (or other mechanically-driven accessories) and also rotationally drives the load compressor 18 which is used to supply compressed air to the pneumatically-operated accessory system 14. Ambient air 44 is drawn through a set of adjustable inlet guide vanes (IGV) 46 into the inlet of the load compressor 18. Compressed air exiting (or "bled" from) compressor 18 is forced through a main bleed air duct 48, and then through a branch bleed

air supply duct 50 connected to main duct 48, to supply compressed air to the accessory system 14. Branch bleed duct 50 is sized to flow to the accessory system 14 the entire volume of compressed air discharged from the load compressor 18.

The amount of compressor bleed air received by system 14 is conventionally regulated by a valve or damper 52, positioned in the branch bleed duct 50, which is controlled by a volume controller 54 operatively connected between the system 14 and the valve 52. Upon sensing an increase in system compressed air demand, the controller 54 modulates valve 52 toward a fully open position. Conversely, upon sensing a decrease in system compressed air demand, the controller 54 modulates valve 52 toward a fully closed position.

The bleed air-producing load compressor 18 is conventionally designed for maximum efficiency at rated load. Therefore, a certain minimum through flow of air is required to prevent compressor surge (i.e., stall on the blades of compressor 18). Because of the varying compressed air demand of accessory system 14, it is necessary to provide an alternate outlet flow path (i.e., in addition to branch bleed air duct 50) for the bleed air flowing through the main duct 48 in the event that the quantity of bleed air flow through branch duct 50 falls below the minimum required to prevent a surge condition in compressor 18. More specifically, when the valve 52 restricts the flow of bleed air in branch duct 50 to below the minimum surge-prevention quantity, an additional bleed air outlet passage must be provided from the main bleed duct 48.

To accomplish this relief function, a surge bleed duct 56 is connected to the main bleed duct 48 and extended therefrom into the APU discharge passage 42. Like the branch bleed duct 50, surge bleed duct 56 is sized to accommodate the entire flow of bleed air through the main duct 48 in the event that the control valve 52 closes completely, in which case all of the bleed air discharged from the load compressor 18 is dumped into the discharge passage 42 through the surge bleed duct 56.

Compressed air flow through the surge bleed duct 56 is regulated by variable surge flow restriction means in the form of a surge bleed valve or damper 58 installed in the surge bleed duct 56. Surge bleed valve 58 is positioned by a torque motor 60 which is powered by bleed air 62 from the second stage power compressor 22.

It is to the control of the surge bleed valve 58, in response to the varying compressed air demands of the accessory system 14, that the present invention is directed. The conventional method of regulating the surge bleed valve 58 is to employ a mechanical control system which senses the pressure within the main bleed duct 48 (or another parameter related to the total air flow therethrough) and generates an error signal indicative of the magnitude of the deviation of such parameter from a desired value thereof. This error signal is used to proportionally control the surge bleed valve to thereby maintain the bleed flow in duct 48 above the minimum required to prevent compressor surge. More specifically, conventional control systems modulate the surge bleed valve to a degree which is simply proportional to the strength of the mechanical error signal. The limitations and disadvantages of proportional surge bleed valve control are well known and are graphically depicted in FIG. 2.

In FIG. 2 point A represents, for a selected inlet guide vane position, the total load compressor bleed air

flow through main duct 48 with surge bleed valve 58 fully closed and accessory valve 52 fully open. The vertical dashed line 64 to the left of point A is the surge line of the load compressor 18, a total compressor bleed flow to the left of the surge line causing compressor surge.

With conventional proportional control of surge bleed valve 58, its control line (dashed line 66 in FIG. 2) is inclined leftwardly relative to the vertical because of the droop characteristics inherent in proportional control. Thus, in order to assure that the total compressor bleed air flow is slightly above its surge flow level (by a suitable safety margin of from 5 to 15 percent) when the surge valve is open to an extent necessary to cause full bleed flow through duct 56 (i.e., at point C, at which point the surge valve is somewhat less than fully open in accordance with customary design practice), it is necessary to initially open the surge valve at point B—a point well to the right of point C. This very early initial opening of the surge valve causes a rather sizable excess of surge bleed air to be dumped to atmosphere to accommodate the proportional control droop. Such excess bleed air is graphically depicted in FIG. 2 by the cross-hatched area between lines 64 and 66.

The large excess surge bleed air requirement of conventional proportional control of the surge bleed valve results in increased fuel consumption of the APU, creates additional bleed air noise, limits the bleed air pressure available to the pneumatically-operated accessory system 14, and reduces the total usable power output of the APU.

The present invention provides a unique electronic control system, indicated generally at 68 in FIG. 1, which inexpensively solves these problems. In a novel manner described below, control system 68 operates the surge bleed valve along a control line 70 (FIG. 2) which is substantially parallel to the surge line 64 and extends through point C just slightly to the right of the surge line. With the control line 70 thus shifted relative to the conventional control line 66, an initial surge valve opening point D is provided which, like point C, is positioned slightly to the right of the surge line. Thus, as the accessory valve 52 begins to close off and the total compressor bleed air flow begins to decrease (i.e., move leftwardly from point A) a much later initial opening of the surge valve occurs. As can readily be seen in FIG. 2, the clockwise rotation of the surge valve control line (relative to the conventional control line 66) by the control system 68 eliminates all of the excess surge bleed flow between lines 66 and 70. The only excess surge bleed air flow remaining, represented by the cross-hatched area between lines 64 and 70, is that necessary to maintain a predetermined margin of safety during operation of the APU.

THE ELECTRONIC SURGE BLEED VALVE CONTROL SYSTEM

Referring now to FIGS. 1, 3 and 4, the electronic control system 68 includes a flow sensor 72, connected to the main bleed air duct 48, which comprises a total pressure transducer 74 and a differential pressure transducer 76. A static pressure probe 78 extends into the main duct 48 and is coupled to the static pressure inlet of the differential transducer 76. Additionally, a total pressure probe 80 extends into the duct 48 and is coupled to the inlet of the total pressure transducer 74 and the total pressure inlet of the differential transducer 76. The flow sensor 72 transmits an output signal which comprises the combination of electric signals 82, 84 from the transducers 74, 76 respectively. Signal 82 is indicative of the total pressure (P_t), and signal 84 is indicative of the difference (P_t-P_s) between the total and static pressures within main duct 48.

Transducer output signals 82, 84 are received by an electronic controller 86 which responsively transmits an electric control signal 88 to the valve motor 60 to vary the amount of power compressor bleed air 62 it receives, and thus vary the modulating force on the normally open surge bleed valve 58 in a manner achieving the very desirable surge valve control line 70 of FIG. 2.

Also received by controller 86 are electric input signals 90, 92, 94 and 96, as indicated in FIGS. 1 and 4, which function as subsequently described to reset the controller 86. Input signal 90 is transmitted to the controller 86 by an inlet guide vane position sensor 98 and is indicative of the acutal position (i.e., opening angle) of the inlet guide vanes 46. Input signal 92 is manually generated and resets controller 86 to an accessory system zero demand (or "idle") mode in which, by means not shown, the inlet guide vanes are closed. Input signal 94, also manually generated, resets controller 86 to an accessory system minimum demand mode and, also by means not shown, moves the inlet guide vane to a predetermined minimum opening position. Input signal 96 emanates from a pressure sensor (not shown) in the load compressor inlet and is indicative of the pressure therein.

Referring now to FIG. 4, the electronic controller 86 includes a divider 100 which receives the pressure transducer output signals 82, 84 and responsively generates an electric output signal 102 whose magnitude represents the value of the sensed control parameter, $(P_t-P_s)/P_t$ of the control system 68.

Reset signals 90, 94, 96 are used to combinatively define a desired value, or set point, of the main bleed flow-related control parameter $(P_t-P_s)/P_t$. Signal 90, emanating from the guide vane position sensor 98, is used to adjust such set point as a function of the angular position of the inlet guide vanes 46. This guide vane-related adjustment is accomplished by a function generator 104 which receives reset signal 90 and responsively generates an output signal 106 related to signal 90 according to a predetermined, generally linearly increasing reset schedule 108 as graphically illustrated in FIG. 4.

As will be seen, the use of the control parameter $(P_t-P_s)/P_t$ and the automatic adjustment of its set point value in response to changes in inlet guide vane position, assure that a constant minimum load compressor bleed flow rate, between the compressor surge rate and the maximum accessory demand flow rate, is maintained by the control system 68 despite wide variations in inlet guide vane position and ambient temperatures.

Signal 94, generated when the accessory system minimum demand mode is manually selected, is received by a signal generator 110 which transmits an output signal 112 whose magnitude is constant.

The third control point reset signal, signal 96, which is indicative of the load compressor inlet pressure, is received by a comparator 114 which also receives an electric reference input signal 116 having a constant magnitude representative of sea level atmospheric pressure. Comparator 114 generates, through a multiplier 118, an output signal 120 which is proportional to the

difference in magnitude between signals 96 and 116, thus being indicative of the actual altitude of APU 10.

The three reset control signals 106, 112, 120, and the signal 102 (which represents the actual sensed value of the flow parameter $(P_t-P_s)/P_t$ within the main bleed duct 48), are received by a comparator 122 which transmits, through a dynamic compensator 124, an error signal 126 whose magnitude is indicative of the difference between the actual value of the flow control parameter and the desired value thereof—namely the sum of the magnitudes of signals 106, 112 and 120. Dynamic compensator 124 functions in a conventional manner to provide lead-lag dynamic compensation to error signal 126, thereby improving its transient response characteristics without affecting its steady state values.

It can be seen in FIG. 4 that the set point value of the main bleed flow parameter $(P_t-P_s)/P_t$ is increased by the control system 68 in three manners—(1) an increased opening of the inlet guide vanes, (2) a selection of the accessory system minimum demand mode and/or (3) an increase in the altitude of the APU. Conversely, the set point is decreased by a reduction in the magnitude of any of the signals 106, 112, 120.

Error signal 126 is supplied in parallel to a proportional controller 128 and an integral controller 130. Controller 128, 130, respectively, transmit electrical output control signals 132, 134 which are received by a summer 136. The magnitude of output signal 132 is a predetermined multiple of the magnitude of error signal 126, while the magnitude of output signal 134 is the integral as a function of time, of the error signal 126.

The summer 136 combines, or superimposes, the proportional and integral control signals 132, 134 and outputs the combined control signal 88 which is used to regulate the torque motor 60 (FIG. 1), and thus modulate the surge bleed valve 58. As can be seen in FIG. 5, the output signal 88 from the electronic controller 86 has a magnitude which linearly increases relative to the magnitude of the error signal 126 as a function of the duration of such error signal, and has, at a given time t, both an integral component I and a proportional component P. The flow rate of surge bleed air exhausted through duct 56 is thus related to the magnitude of deviation of the parameter $(p_t-P_s)/P_t$ from its set point value, in both a proportional and time-integral manner.

It is this unique use of proportional and integral system control, afforded by the parallel controllers 128, 130, which imparts the characteristics to the ultimate valve-controlling signal 88 that substantially eliminate the excess surge bleed problems previously described and long-associated with conventional proportional control of surge bleed valve 58.

More specifically, it has been discovered that this addition to the valve-controlling signal 88 of the integral component I (i.e., the integrated output signal 134) makes possible the ideally positioned valve control line 70 (FIG. 2), thereby eliminating the previously unavoidable wastage of surge bleed air represented by the area between lines 66 and 70 in FIG. 2. The resulting control line 70, since it is essentially parallel to surge line 64, greatly delays the required initial opening of the surge valve (compared to conventional proportional valve control), as previously described, when the total compressor bleed air flow rate begins to diminish.

In sum, the illustrated control system 68 provides a constant minimum total bleed air flow rate (line 70) instead of the wasteful varying minimum flow rate (line 66) of previous surge valve control systems. Under the greatly improved control of system 68, once the surge valve 58 is initially opened the flow through main duct 48 remains essentially constant regardless of degree to which the surge valve is further opened.

Referring again to FIG. 4, the error signal 126 received by the parallel controllers 128, 130 is also transmitted to a "kicker" control 138. When error signal 126 reaches a predetermined maximum level (indicating a predetermined maximum deviation between the actual value of the flow parameter $(p_t-P_s)/P_t$ and its set point), the kicker 138 transmits a constant value output signal 140 to an OR gate 142 which also receives signal 92 (the manually selected accessory system zero demand signal). If the OR gate 142 receives either of the signals 92, 140 it immediately transmits to the integral controller 130 an electrical integrator shutoff signal 144 which interrupts current flow therethrough, thereby allowing the surge valve 58 to move, at its maximum slew rate, toward its normally open position.

Thus, for example, if the total bleed flow rate in main duct 48 experiences a very rapid diminution, the kicker 138 acts as a safety mechanism to compensate for this condition by snapping the surge valve to a more open position until the error signal returns to below its predetermined maximum allowable level. Selection, via signal 92, of the zero accessory system demand mode, which closes the accessory valve in a manner not shown, also de-energizes the integrator 130 and rapidly opens the surge valve to prevent compressor stall which might otherwise result from a sudden closing of the accessory valve.

As previously mentioned, the selection of the flow-related main bleed air control parameter $(p_t-P_s)/P_t$ affords the control system certain operational advantages. Such advantages will now be described with reference to FIG. 6.

In FIG. 6 two sets of constant temperature load compressor operating lines, 146*a*, 146*b* and 146*c*, and 148*a*, 148*b* and 148*c*, are plotted against the coordinates of load compressor outlet-to-inlet pressure ratio and corrected load compressor inlet air flow for two representative inlet guide vane angles, 70° and 35°. For the 70° inlet guide vane angle the load compressor surge line is represented by dashed line 150, while the surge line of the load compressor for the 35° inlet guide vane angle is represented by dashed line 152. To the right of, and substantially parallel to, the surge lines 150, 152 are plotted representative maximum accessory system flow rate demand lines 154, 156 which respectively correspond to the 70° and 35° guide vane angles.

Finally, there are plotted on the graph of FIG. 6 two control parameter lines 158, 160, each of which represents a different constant value of the main bleed duct flow parameter $(P_t-P_s)/P_t$ used in the preferred embodiment of the present invention.

Two important characteristics of the parameter lines 158, 160 should be noted. First, each such line, as it passes through the compressor operating lines, has a constant slope, indicating that the selected parameter $(P_t-P_s)/P_t$ is insensitive to variations in compressor inlet (i.e., ambient) temperature. Secondly, each of the parameter lines 158, 160 extends between and is essentially parallel to a different one of the surge and demand line pairs 150, 154 and 152, 156. The lines 158, 160 thus respectively define ideal potential load compressor operating areas 162 (the cross-hatched area bounded by lines 146*a*, 156, 146*c* and 158) and 164 (the cross-hatched area bounded by lines 148*a*, 156, 148*c* and 160),

such potential operating areas having substantially constant minimum flow rates paralleling their associated surge lines.

The achievement of these optimum compressor operating areas, defined in part by the flow parameter lines 158, 160, is, of course, made possible by the previously described novel integral and proportional surge valve control built into the control system 68.

Another reason why the use of this particular flow control parameter is operationally advantages is that the optimum value of such parameter for each guide vane angle is essentially linearly related to the particular inlet guide vane angle. This generally linear relationship permits the use of the relatively simple linear function generator 104 (FIG. 4) to properly reset the desired value of the flow parameter as a function of the inlet guide vane position.

The bleed air control principles of the present invention are applicable to a wide variety of compressor bleed applications and are not limited to the APU load compressor application described above. For example, the proportional-plus-integral surge valve control method of the present invention is equally well adapted to the situation where partial bleed-off of the compressed air discharged from a power compressor (as distinguished from a load compressor) is used as the air source for a pneumatically-operated accessory system.

Additionally, while the control parameter $(P_t-P_s)/P_t$ is particularly well suited to the illustrated load compressor bleed application, other flow-related parameters (such as P_t-P_s) could be used if desired. Moreover, the signals used to adjust the control set point (i.e., the illustrated altitude, minimum demand mode, and inlet guide vane adjustment signals) could be varied to suit the particular bleed air application. One example of such variation would be the deletion of the guide vane adjustment of the control set point in the situation where the bled-from compressor does not have adjustable guide vanes.

To summarize, the control system 68, with its integral-plus-proportional control feature, provides apparatus and methods for eliminating the large amount of wasted surge bleed air associated with previous surge valve control systems. This is accomplished by using relatively standard, rugged and reliable electronic components. The greatly improved control provided by this invention reduces fuel consumption and surge bleed air usage and noise, yet at the same time increases the maximum air pressure available to the pneumatic accessory system 14 and the maximum shaft power available to the mechanically-driven accessory 12.

The foregoing detailed description is to be clearly understood as given by way of illustration and example only, the spirit and scope of this invention being limited solely by the appended claims.

What is claimed is:

1. A system for supplying gas discharged from a compressor or the like to gas-operated apparatus having a variable gas flow rate demand, the compressor having an inlet opening and means for variably adjusting the area of such inlet opening, said system comprising:

(a) duct means for flowing to the gas-operated apparatus gas discharged from the compressor;

(b) means defining a surge outlet passage from said duct means;

(c) surge flow regulating means operable to variably restrict gas flow outwardly through said surge outlet passage;

(d) means for sensing the value of a predetermined flow-related parameter within said duct means and generating an error signal having a magnitude indicative of the deviation between the sensed value of said parameter and a desired value thereof, said sensing and generating means including comparator means for comparing the sensed value of said parameter to a set point value thereof and responsively generating said error signal;

(e) control means for utilizing said error signal to operate said surge flow regulating means in a manner providing an essentially constant minimum gas flow rate through said duct means despite fluctuations in the flow rate of gas received by the gas-operated apparatus; and

(f) means associated with said comparator means for varying said set point value of said parameter in response to variation in the area of the compressor inlet opening.

2. The system of claim 1 in which said flow-related parameter is $(P_t-P_s)/P_t$, P_t being the total pressure in said duct means and P_s being the static pressure therein.

3. A control system for modulating a surge bleed valve positioned in a surge bleed outlet passage of bleed duct means adapted to receive air discharged from a compressor and supply the air to pneumatically-operated apparatus having a variable supply air demand, the compressor having adjustable inlet guide vanes, said control system comprising:

(a) means for generating an error signal indicative of the difference between the actual magnitude of a selected flow-related parameter within the bleed duct means and a desired value of said parameter, said error signal generating means including:

(1) means for sensing the difference between the total pressure and the static pressure within the bleed duct means and transmitting a first output signal indicative of the sensed pressure differential,

(2) means for sensing the total pressure within the bleed duct means and transmitting a second output signal indicative of the sensed total pressure,

(3) means for generating a sensed parameter signal having a magnitude equal to the magnitude of said first output signal divided by the magnitude of said second output signal, and

(4) comparator means for receiving said sensed parameter signal and at least one reset signal indicative of said desired value of said parameter, and for responsively generating said error signal;

(b) first control means for receiving said error signal and transmitting an output signal having a magnitude proportional to the magnitude of said error signal;

(c) second control means for receiving said error signal and transmitting an output signal having a magnitude representing the integral, as a function of time, of the magnitude of said error signal;

(d) means for simultaneously utilizing said output signals from said first and second control means to modulate the surge bleed valve in a manner assuring that the minimum air flow rate through the bleed duct means is of a substantially constant, predetermined magnitude regardless of the supply air demand of the pneumatically-operated apparatus; and

(e) guide vane position sensor means for transmitting said reset signal to said comparator means, said

reset signal varying as a function of the position of the inlet guide vanes according to a predetermined reset schedule.

4. The control system of claim 3 wherein said reset schedule is substantially linear.

5. The control system of claim 3 wherein said elements (a) through (d) are electronic.

6. For use with an air supply system for pneumatically-powered apparatus having a variable supply air demand, the system including a supply duct interconnected between a compressor and the pneumatically-powered apparatus and having a surge outlet passage in which is positioned a surge bleed valve, control apparatus for modulating the valve comprising:

(a) means, responsive to a variation in the flow rate of compressor discharge air through the supply duct, for producing an error signal having a magnitude indicative of the degree of deviation, from a desired minimum flow rate, of the actual flow rate through the supply duct;

(b) control means for utilizing said error signal to modulate the surge bleed valve in a manner such that, subsequent to an initial opening of the valve, the air flow rate through the supply duct remains substantially constant regardless of the degree to which the valve is further opened, whereby the valve is controlled along an operating line substantially parallel to a surge line of the compressor, said control means including means for receiving said error signal and responsively transmitting to the surge valve a control signal whose magnitude has, relative to the magnitude of said error signal, both a proportional component and a time-integral component, said means for receiving said error signal including a proportional controller, an integral controller and a summer, said proportional and integral controllers being coupled in parallel between said error signal-producing means (a) and said summer, said summer having an outlet coupled to the surge valve; and

(c) means for automatically deleting said time-integral component from said control signal while said error signal exceeds a predetermined magnitude.

7. The control apparatus of claim 6 wherein said means for automatically deleting said time-integral component comprises a kicker device having inlet means for receiving said error signal, said kicker device further having means for deactivating said integral controller when said error signal reaches a predetermined magnitude.

8. A gas turbine engine accessory power unit having a fluctuating compressed air supply demand, said accessory power unit comprising:

(a) a compressor having adjustable inlet guide vanes;

(b) duct means for receiving compressed air discharged from said compressor and supplying the received air to the pneumatically-powered apparatus;

(c) surge bleed means operable to exhaust from said duct means a selectively variable quantity of air to assure at least a predetermined minimum flow rate through said duct means and thereby prevent surge of said compressor;

(d) sensing means for sensing the value of a predetermined, flow-related parameter within said duct means and generating an output signal indicative of said value, said value of said flow-related parameter being substantially independent of the temperature of the compressed air;

(e) comparator means for receiving said sensing means output signal and generating an error signal representing the difference between the sensed value of said parameter and a desired value thereof, said comparator means having an adjustable control set point representing said desired value of said parameter;

(f) means for transmitting to said comparator means a reset signal for varying said set point as a function of the position of said inlet guide vanes in accordance with a predetermined reset schedule; and

(g) control means for receiving said error signal and transmitting to said surge bleed means a control signal to operate said surge bleed means, the magnitude of said control signal having, relative to the magnitude of said error signal, a proportional component and an integral component,

whereby said minimum flow rate through said duct means is essentially constant regardless of the compressed air supply demand of the pneumatically-powered apparatus.

9. The accessory power unit of claim 8 wherein said parameter is $(P_t-P_s)/P_t$, P_t and P_s respectively being the total and static pressures within said duct means, and said reset schedule is at least approximately linear.

10. The accessory power unit of claim 8 wherein said control means include parallel proportional and integral controllers coupled to a summer having an outlet connected to said surge bleed means.

11. The accessory power unit of claim 8 wherein said sensing means include at least one pressure-to-electric transducer, and said comparator means and said control means comprise electronic components.

12. A gas turbine engine device comprising:

(a) drivable compressor means for receiving, compressing, and discharging air, said compressor means having adjustable inlet guide vanes;

(b) combustor means for receiving compressed air discharged by said compressor means, mixing the received air with fuel, burning the fuel-air mixture, and discharging the resultant expanded gas;

(c) turbine means, positioned to be operated by the expanded gas discharged from said combustor means, for driving said compressor means and creating a power output from said gas turbine device;

(d) a bleed air system including:

(1) main bleed duct means for receiving air discharged from said compressor means, said main bleed duct means having a branch supply portion for flowing compressed air to pneumatically-operated apparatus having a fluctuating compressed air supply demand, said main bleed duct means further having a surge bleed outlet portion for exhausting air from said main bleed duct means,

(2) flow regulating means operable to vary the flow rate of air exhausted through said surge bleed output portion of said main bleed duct means, and

(3) surge bleed control means for operating said flow regulating means to assure an essentially constant minimum air flow rate through said main bleed duct means despite fluctuations in the air flow rate through said branch supply portion of said main bleed duct means, said surge bleed control means being responsive to variations in

air flow through said main bleed duct means and including means for integrally and proportionally controlling said flow regulating means, said surge bleed control means further including means for sensing a predetermined, flow-related parameter within said main bleed duct means and generating an output signal indicative of the sensed value of said parameter, comparator means for receiving said sensing means output signal and generating an error signal indicative of the variation between the actual magnitude of said sensing means output signal and a desired set point value thereof, said means for integrally and proportionally controlling said flow regulating means including means for receiving said error signal and converting the same to a control signal whose magnitude, relative to the magnitude of said error signal, has both a proportional and a time-integral component; and

(e) means, connected between said inlet guide vanes and said comparator means, for varying said set point value as a function of the position of said inlet guide vanes.

13. The device of claim 12 wherein said means for sensing the air flow rate through said main bleed duct means include means for sensing therein the parameter $(P_t-P_s)/P_t$, P_t being the total pressure in said main bleed duct means and P_s being the static pressure therein, and wherein the degree to which said set point value is altered by said set point varying means is substantially linearly related to the position of said inlet guide vanes.

14. The device of claim 13 wherein said means for sensing the flow rate through said main bleed duct means comprise a total pressure-to-electric transducer coupled to a differential pressure-to-electric transducer, and a signal divider coupled to each of said transducers.

15. The device of claim 12 wherein said compressor means include a load compressor, said inlet guide vanes are associated with said load compressor, and said main bleed duct means are positioned to receive compressed air discharged from said load compressor.

16. The device of claim 12 further comprising means for automatically varying said set point value in response to changes in the altitude of said device.

17. A gas turbine engine device comprising:

(a) drivable compressor means for receiving, compressing and discharging air;

(b) combustor means for receiving compressed air discharged by said compressor means, mixing the received air with fuel, burning the fuel-air mixture, and discharging the resultant expanded gas;

(c) turbine means, positioned to be operated by the expanded gas discharged from said combustor means, for driving said compressor means and creating a power output from said gas turbine device; and

(d) a bleed air system including;

(1) main bleed duct means for receiving air discharged from said compressor means, said main bleed duct means having a branch supply portion for flowing compressed air to pneumatically-operated apparatus having a fluctuating compressed air supply demand, said main bleed duct means further having a surge bleed outlet portion for exhausting air from said main bleed duct means,

(2) flow regulating means operable to vary the flow rate of air exhausted through said surge bleed output portion of said main bleed duct means, said flow regulating means including a normally open surge bleed valve, and

(3) surge bleed control means for operating said flow regulating means to assure an essentially constant minimum air flow rate through said main bleed duct means despite fluctuations in the air flow rate through said branch supply portion of said main bleed duct means, said surge bleed control means being responsive to variations in air flow through said main bleed duct means and including means for integrally and proportionally controlling said flow regulating means, said surge bleed control means further including proportional controller means for receiving said error signal and generating a first output signal, integral controller means for receiving said error signal and generating a second output signal, and means for simultaneously utilizing the first and second output signals to operate said flow regulating means, said surge bleed control means further including means for deactivating said integral controller means during periods when said error signal exceeds a predetermined magnitude.

18. A control system for assuring a substantially constant minimum flow rate through a duct receiving air discharged from a compressor or the like, the duct having a supply outlet connected to penumatically-operated apparatus having a variable supply air demand, the duct further having an exhaust outlet, said control system comprising;

(a) a flow regulating device adapted to be positioned in the exhaust outlet and operable to selectively vary air flow outwardly therethrough;

(b) a sensing device having a sensing portion adapted to be positioned in the duct to sense therein a predetermined parameter related to the air flow rate through the duct, said flow sensing device further having an output portion;

(c) an adjustable set point comparator having an input portion coupled to said output portion of said sensing device, and an output adapted to generate an error signal;

(d) a proportional controller having an inlet coupled to said outlet of said comparator and further having an outlet;

(e) an integral controller having an inlet coupled to said outlet of said comparator and further having an outlet;

(f) a summer having a first inlet coupled to said outlet of said proportional controller, a second inlet coupled to said outlet of said integral controller, and an outlet coupled to said flow regulating device; and

(g) a kicker connected between said outlet of said comparator and said integral controller to deactivate said integral controller when said error signal reaches a predetermined magnitude.

19. A control system for assuring a substantially constant minimum flow rate through a duct receiving air discharged from a compressor or the like having adjustable inlet guide vanes, the duct having a supply outlet connected to pneumatically-operated apparatus having a variable supply air demand, the duct further having an exhaust outlet, said control system comprising:

(a) a flow regulating device adapted to be positioned in the exhaust outlet and operable to selectively vary air flow outwardly therethrough;

(b) a sensing device having a sensing portion adapted to be positioned in the duct to sense therein a predetermined parameter related to the air flow rate through the duct, said sensing device further having an output portion;

(c) an adjustable set point comparator having an input portion coupled to said output portion of said sensing device, and an outlet adapted to generate an error signal;

(d) a proportional controller having an inlet coupled to said output of said comparator and further having an outlet;

(e) an integral controller having an inlet coupled to said outlet of said comparator and further having an outlet;

(f) a summer having a first inlet coupled to said outlet of said proportional controller, a second inlet coupled to said outlet of said integral controller, and an outlet coupled to said flow regulating device; and

(g) a guide vane position sensor and a function generator coupled in series between the inlet guide vanes and said input portion of said comparator.

20. The control system of claim 19 wherein the output of said function generator is generally linearly related to its input.

21. The control system of claim 19 further comprising an additional comparator having a first inlet adapted to receive a signal indicative of the actual altitude of said control system, a second inlet adapted to receive a reference altitude signal, and an outlet coupled to said input portion of first-mentioned comparator.

22. The control system of claim 19 wherein said flow sensing device comprises a total pressure transducer coupled to a differential pressure transducer, each of said transducers having an outlet, and wherein said control system further comprises a signal divider having a pair of inlets each coupled to one of said transducer outlets, and an outlet coupled to said input portion of said comparator.

23. The control system of claim 19 wherein said control system is electronic.

* * * * *

JTX 31

235794 APR 26 1983 NUMBER PATENT 4380893

SERIAL NUMBER	FILING DATE	CLASS	SUBCLASS	GROUP ART UNIT	EXAMINER
06/235,794	02/19/81	060		343	

APPLICANTS: RICHARD F. STOCKES, PHOENIX, AZ; JAMES C. TIMM, TEMPE, AZ; STEPHEN R. LA CROIX, SCOTTSDALE, AZ; MILTON R. ADAMS, TEMPE, AZ.

241-97-104
85
4-32-2-3-2

CONTINUING DATA********************
VERIFIED

FOREIGN/PCT APPLICATIONS**********
VERIFIED

Foreign priority claimed 35 USC 119 conditions met / Verified and Acknowledged	AS FILED	STATE OR COUNTRY	SHEETS DRWGS.	TOTAL CLAIMS	INDEP. CLAIMS	FILING FEE RECEIVED	ATTORNEY'S DOCKET NO.
yes / no		AZ	2	52	9	$ 229	TE-4086

ADDRESS:
~~THE GARRETT CORP.~~ J. Richard Konneker 124/301-1S
PAT. DEPARTMENT 64/301-1
111 SOUTH 34TH ST.
P. O. BOX 5217
PHOENIX, AZ 85010

TITLE: COMPRESSOR BLEED AIR CONTROL APPARATUS AND METHOD

U.S. DEPT. of COMM.-Pat. & TM Office — PTO-436L (rev. 10-78)

HSB 401406

PARTS OF APPLICATION FILED SEPARATELY

PREPARED FOR ISSUE

(Assistant Examiner) (Docket Clerk)

EXAMINED AND PASSED FOR ISSUE

J. CASARREGOLE
EXAMINER
ART UNIT 343

(Primary Examiner) (Art Unit)

AT ALLOWANCE

SHEETS DRWGS.	FIGURES DRWGS.	CLAIMS	CLASS	SUBCLASS
2	6	22	60	39.07

Estimate of printed pages: Drawing(s) | Spec(s) | Issue fee due $

Notice of allowance and issue fee due (est.)
Date mailed | Date 1-21-83

RETENTION LABEL

REMAND
JTX 31

16. A gas turbine engine accessory power unit for supplying compressed air to pneumatically-powered apparatus having a fluctuating compressed air supply demand, said accessory power unit comprising:

(a) a compressor;

(b) duct means for receiving compressed air discharged from said compressor and supplying the received air to the pneumatically-powered apparatus;

(c) surge bleed means operable to exhaust from said duct means a selectively variable quantity of air to assure at least a predetermined minimum flow rate through said duct means and thereby prevent surge of said compressor;

(d) sensing means for sensing the value of a predetermined, flow-related parameter within said duct means and generating an output signal indicative of said value;

(e) comparator means for receiving said sensing means output signal and generating an error signal representing the difference between the sensed value of said parameter and a desired value thereof; and

(f) control means for receiving said error signal and transmitting to said surge bleed means a control signal to operate said surge bleed means, the magnitude of said control signal having, relative to the magnitude of said error signal, a proportional component and an integral component,

whereby said minimum flow rate through said duct means is essentially constant regardless of the compressed air supply demand of the pneumatically-powered apparatus.

HSB 401434

30. The device of Claim 29 wherein said flow regulating means include a normally open surge bleed valve, and said surge bleed control means further include means for deactivating said integral controller means during periods when said error signal exceed a predetermined magnitude.

31. The device of Claim 30 wherein said surge bleed control means further include means for deactivating said integral control means in response to the selection of a predetermined mode of operation of the pneumatically-operated apparatus.

32. A control system for assuring a substantially constant minimum flow rate through a duct receiving air discharged from a compressor or the like, the duct having a supply outlet connected to pneumatically-operated apparatus having a variable supply air demand, the duct further having an exhaust outlet, said control system comprising:

(a) a flow regulating device adapted to be positioned in the exhaust outlet and operable to selectively vary air flow outwardly therethrough;

(b) a flow sensing device having a sensing portion adapted to be positioned in the duct, said flow sensing device further having an output portion;

(c) an adjustable set point comparator having an input portion coupled to said output portion of said flow sensor, and an outlet adapted to generate an error signal;

(d) a proportional controller having an inlet coupled to said outlet of said comparator and further having an outlet;

(e) an integral controller having an inlet coupled to said outlet of said comparator and further having an inlet; and

(f) a summer having a first inlet coupled to said outlet of said proportional controller, a second inlet coupled to said outlet of said integral controller, and an outlet coupled to said flow regulator.

33. The control system of Claim 32 further comprising a kicker connected between said outlet of said comparator and said integral controller to deactivate said integral controller when said error signal reaches a predetermined magnitude.

34. The control system of Claim 33 further compising an OR gate having a first inlet adapted to receive a signal indicating the selection of a predetermined mode of operation of the pneumatically-operated apparatus, a second inlet, and an outlet coupled to said integral controller, and wherein said kicker has an inlet coupled to said outlet of said comparator, and an outlet coupled to said second inlet of said OR gate.

35. The control system of Claim 32 wherein the compressor has adjustable inlet guide vanes, and said control system further comprises a guide vane position sensor and a function generator coupled in series between the inlet guide vanes and said input portion of said comparator.

Patent and Trademark Office
Address COMMISSIONER OF PATENTS AND TRADEMARKS Washington, D.C. 20231

SERIAL NUMBER	FILING DATE	FIRST NAMED APPLICANT	ATTORNEY DOCKET

EXAMINER	
ART UNIT	PAPER NUMBER
	4

DATE MAILED

This is a communication from the examiner in charge of your application.
COMMISSIONER OF PATENTS AND TRADEMARKS

X This application has been examined ☐ Responsive to communication filed on ____________ ☐ This action is made final.

A shortened statutory period for response to this action is set to expire 3 month(s), ______ days from the date of this letter.
Failure to respond within the period for response will cause the application to become abandoned. 35 U.S.C. 133

Part I THE FOLLOWING ATTACHMENT(S) ARE PART OF THIS ACTION:

1. X Notice of References Cited by Examiner, PTO-892.
2. ☐ Notice re Patent Drawing, PTO-948.
3. ☐ Notice of Art Cited by Applicant, PTO-1449
4. ☐ Notice of Informal Patent Application, Form PTO-152
5. ☐ Information on How to Effect Drawing Changes, PTO-1474
6. ☐ ____________

Part II SUMMARY OF ACTION

1. X Claims 1-52 are pending in the application.
   Of the above, claims 41-52 are withdrawn from consideration.
2. ☐ Claims ____________ have been cancelled.
3. ☐ Claims ____________ are allowed.
4. X Claims 1-7, 10-16, 19-40 are rejected.
5. X Claims 8, 9, 17, 18 are objected to.
6. ☐ Claims ____________ are subject to restriction or election requirement.
7. ☐ This application has been filed with informal drawings which are acceptable for examination purposes until such time as allowable subject matter is indicated.
8. ☐ Allowable subject matter having been indicated, formal drawings are required in response to this Office action.
9. ☐ The corrected or substitute drawings have been received on ____________. These drawings are ☐ acceptable; ☐ not acceptable (see explanation).
10. ☐ The ☐ proposed drawing correction and/or the ☐ proposed additional or substitute sheet(s) of drawings, filed on ____________ has (have) been ☐ approved by the examiner. ☐ disapproved by the examiner (see explanation).
11. ☐ The proposed drawing correction, filed ____________, has been ☐ approved. ☐ disapproved (see explanation). However, the Patent and Trademark Office no longer makes drawing changes. It is now applicant's responsibility to ensure that the drawings are corrected. Corrections MUST be effected in accordance with the instructions set forth on the attached letter "INFORMATION ON HOW TO EFFECT DRAWING CHANGES", PTO-1474.
12. ☐ Acknowledgment is made of the claim for priority under 35 U.S.C. 119. The certified copy has ☐ been received ☐ not been received ☐ been filed in parent application, serial no. ____________; filed on ____________.
13. ☐ Since this application appears to be in condition for allowance except for formal matters, prosecution as to the merits is closed in accordance with the practice under Ex parte Quayle, 1935 C.D. 11; 453 O.G. 213.
14. ☐ Other

HSB 401454

Restriction to one of the following inventions is required under 35 U.S.C. 121:

I. Claims 1-40, drawn to a compressor control apparatus, classified in Class 60, subclass 39.07.

II. Claims 41-52, drawn to a compressor control process, classified in Class 60, subclass 39.02.

The inventions of groups I and II above are distinct because the process of group II can be practiced with apparatus materially different than that of group I, and the apparatus of group I can be used in conjunction with a process materially different than that of group II (MPEP 806.05(e)).

Because the inventions are distinct for the reasons given above and require separate classification and divergent fields of search, restriction for examination purposes as indicated is proper.

During a telephone conversation on 8/27/82, applicants' representative, Mr. Konneker, elected the invention of group I (claims 1-40). The election was made with traverse. An action on the merits of elected claims 1-40 is set forth below and non-elected claims 41-52 are withdrawn from consideration.

Claims 1-5, 11-15, and 21-40 are rejected under 35 U.S.C. 112, second paragraph, as being indefinite for failing to particularly point out and distinctly claim the subject matter which the applicant regards as his or her invention. Claims 1-5 and 11-15 recite "flow rate" as a sensed, control parameter. This limitation is inaccurate

and misleading since the invention, as discloses, senses pressure and not flow rate.

Claims 21-40 recite "air flow" or "flow" as the control parameter. While the intended meaning of these terms ~~are~~ is not entirely clear, they appear to connote "flow rate" and are deemed inaccurate for the same reasons as are claims 1-5 and 11-15.

In claims 28, 31, 34, and 37, reference to a predetermined mode of operation is vague and ambiguous.

Claims 1 and 11 are rejected under 35 U.S.C. 102(b) as anticipated by Metot et al because the invention was patented or described in a printed publication in this or a foreign country, more than one year prior to the date of the application for patent in the United States. Attention is called to sensor 20, error signal generator 26 and dump valve 18.

Claims 1-3, 6, 10-13, 32, 37, 39, and 40 are rejected under 35 U.S.C. 103 as being unpatentable over Shell in view of Rateau or Metot et al. Although, the invention is not identically disclosed or described as set forth in section 102 of Title 35 U.S.C., the differences between the subject matter sought to be patented and the prior art are such that the subject matter as a whole would have been obvious at the time the invention was made to a person having ordinary skill in the art to which said subject matter pertains.

Shell discloses a compressor control system including surge control passage 9 with valve 10, P and Δ P sensors 3 and 11, dividing circuit 14, and controller 15.

Controller 15 compares the quotient from circuit 14 with set point 16; note that the controller in figure 2 has both proportional and integral action.

It is further noted that Shell's surge control outlet recycles air to the compressor inlet. Applicants' claims are not interpretted as specifically precluding this, but even if they were so interpretted, the provision for dumping instead of recycling this air is well known in the art as evidenced by Rateau and Metot.

Claim 7 is rejected like claims 1-3, 6, 10-13, etc. above and in view of Best. The pressure difference employed in the control parameter of the Shell system is taken across an orifice, however, the use of the difference between total and static pressure would be an obvious alternative since it has been applied in other similar systems. See for example, the embodiment of Figure 5 of Best; note pressure taps and 196 and 198, and note also that these taps may be located in the compressor discharge (column 8, lines 4-7). Furthermore, it is pointed out that Rateau provides an additional example of the use of total and static pressure; note elements l and m.

Claims 16, 19-22, 27-29, and 38 are rejected like claims 1-3, 6, 10-13, etc. above and in view of Lewis. The Shell control system is obviously applicable to any dynamic compressor including gas turbine driven compressor means such as those disclosed by Lewis. Note also that the Lewis device is intended for aircraft use and thus the addition of an attitude compensation feature to the control system would be an obvious expedient.

Banner and Schlirf are cited as further pertinent examples of prior art.

Claims 8, 9, 17, and 18 will be allowed if rewritten in independent form. Claims 4, 5, 14, 15, 23-26, 30, 31, and 33-36 will also be allowed if amended to overcome the rejection under 35 USC 112 and rewritten in independent form.

The prior art submitted by applicants is noted but will not be cited or fully considered because of applicants' failure to provide an appropriate "explanation of the relevance of <u>each</u> listed item" as required by 37 CFR 1.98(a). Applicants' broad statement that the references "relate to the control of valves in various pressure regulating systems" is not deemed an adequate explanation of relevance.

L.J.Casaregola:mlr
703 557-3464
9/13/82

L. J. Casaregola
...ARREGOL
EXAMINER
... UNIT 343

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

GROUP ART UNIT 343

EXAMINER: L. J. CASAREGOLA

RECEIVED

GROUP 340

In re Application of RICHARD F. STOKES et al	)	FOR: COMPRESSOR BLEED AIR CONTROL APPARATUS AND METHODS
Serial No. 235,794	)	
Filed: February 19, 1981	)	

AMENDMENT

Hon. Commissioner of Patents
& Trademarks

Washington, D. C. 20231

Phoenix, Arizona 85010

October 25, 1982

Dear Sir:

Responsive to the Office Action dated September 17, 1982, please amend the above-identified application as follows:

IN THE SPECIFICATION:

On page 14, line 7, delete "sume" and insert --sum-- in place thereof, and in line 8 delete "magnitude" and insert --magnitudes-- in place thereof.

IN THE CLAIMS:

Cancel Claims 1-3, 6, 7, 11-13, 16, 21, 22, 28, 29, 31, 32, 34, 37, and 41-52 without prejudice.

Rewrite Claims 4, 8, 14, 17, 23, 30, 33 and 35 in independent form as follows.

--~~14~~ 6. (Amended) [The control apparatus of Claim 13 further comprising] For use with an air supply system for pneumatically-powered apparatus having a variable supply air demand, the system including a supply duct interconnected between a compressor and the pneumatically-powered apparatus and having a surge outlet passage in which is positioned a surge bleed valve, control apparatus for modulating the valve comprising:

(a) means, responsive to a variation in the flow rate of compressor discharge air through the supply duct, for producing an error signal having a magnitude indicative of the degree of deviation, from a desired minimum flow rate, of the actual flow rate through the supply duct;

(b) control means for utilizing said error signal to modulate the surge bleed valve in a manner such that, subsequent to an initial opening of the valve, the air flow rate through the supply duct remains substantially constant regardless of the degree to which the valve is further opened, whereby the valve is controlled along an operating line substantially parallel to a surge line of the compressor, said control means including means for receiving said error signal and responsively transmitting to the surge valve a control signal whose magnitude has, relative to the magnitude of said error signal, both a proportional component and a time-integral component, said means for receiving said error signal including a proportional controller, an integral controller and a summer, said proportional and integral controllers being coupled in parallel between said error signal-producing means (a) and said summer, said summer having an outlet coupled to the surge valve; and

(c) means for automatically deleting said time-integral component from said control signal while said error signal exceeds a predetermined magnitude.--

~~17~~ 8. (Amended) [The accessory power unit of Claim 16 wherein said compressor has] A gas turbine engine accessory power unit having a fluctuating compressed air supply demand, said accessory power unit comprising:

(a) a compressor having adjustable inlet guide vanes[,];

(b) duct means for receiving compressed air discharged from said compressor and supplying the received air to the pneumatically-powered apparatus;

(c) surge bleed means operable to exhaust from said duct means a selectively variable quantity of air to assure at least a predetermined minimum flow rate through said duct means and thereby prevent surge of said compressor;

(d) sensing means for sensing the value of a predetermined, flow-related parameter within said duct means and generating an output signal indicative of said value, [the] said value of said flow-related parameter [is] being substantially independent of the temperature of the compressed air[,];

(e) comparator means for receiving said sensing means output signal and generating an error signal representing the difference between the sensed value of said parameter and a desired value thereof, said comparator means [have] having an adjustable control set point representing said desired value of said parameter [, and said accessory power unit further comprises];

(f) means for transmitting to said comparator means a reset signal for varying said set point as a function of the position of said inlet guide vanes in accordance with a predetermined reset schedule; and

[(f)](g) control means for receiving said error signal and transmitting to said surge bleed means a control signal to operate said surge bleed means, the magnitude of said control signal having, relative to the magnitude of said error signal, a proportional component and an integral component,

whereby said minimum flow rate through said duct means is essentially constant regardless of the compressed air supply demand of the pneumatically-powered apparatus.--

--~~23~~ 12. (Amended) [The device of Claim 22 wherein said compressor means include] A gas turbine engine device comprising:

(a) drivable compressor means for receiving, compressing, and discharging air, said compressor means having adjustable [compressor] inlet guide vanes[,];

(b) combustor means for receiving compressed air discharged by said compressor means, mixing the received air with fuel, burning the fuel-air mixture, and discharging the resultant expanded gas;

(c) turbine means, positioned to be operated by the expanded gas discharged from said combustor means, for driving said compressor means and creating a power output from said gas turbine device;

(d) a bleed air system including:

(1) main bleed duct means for receiving air discharged from said compressor means, said main bleed duct means having a branch supply portion for flowing compressed air to pneumatically-operated apparatus having a fluctuating compressed air supply demand, said main bleed duct means further having a surge bleed outlet portion for exhausting air from said main bleed duct means,

--16. (Amended) [The device of Claim 29 wherein] A gas turbine engine device comprising:

(a) drivable compressor means for receiving, compressing and discharging air;

(b) combustor means for receiving compressed air discharged by said compressor means, mixing the received air with fuel, burning the fuel-air mixture, and discharging the resultant expanded gas;

(c) turbine means, positioned to be operated by the expanded gas discharged from said combustor means, for driving said compressor means and creating a power output from said gas turbine device; and

(d) a bleed air system including:

(1) main bleed duct means for receiving air discharged from said compressor means, said main bleed duct means having a branch supply portion for flowing compressed air to pneumatically-operated apparatus having a fluctuating compressed air supply demand, said main bleed duct means further having a surge bleed outlet portion for exhausting air from said main bleed duct means,

(2) flow regulating means operable to vary the flow rate of air exhausted through said surge bleed output portion of said main bleed duct means, said flow regulating means [include] including a normally open surge bleed valve, and

(3) surge bleed control means for operating said flow regulating means to assure an essentially constant minimum air flow rate through said main bleed duct means despite fluctuations in the air flow rate through said branch supply portion of said

main bleed duct means, said surge bleed control means being responsive to variations in air flow through said main bleed duct means and including means for integrally and proportionally controlling said flow regulating means, said surge bleed control means further including proportional controller means for receiving said error signal and generating a first output signal, integral controller means for receiving said error signal and generating a second output signal, and means for simultaneously utilizing the first and second output signals to operate said flow regulating means, said surge bleed control means further [include] including means for deactivating said integral controller means during periods when said error signal exceeds a predetermined magnitude.--

--~~33~~ 18. (Amended) [The control system of Claim 32 further comprising] A control system for assuring a substantially constant minimum flow rate through a duct receiving air discharged from a compressor or the like, the duct having a supply outlet connected to pneumatically-operated apparatus having a variable supply air demand, the duct further having an exhaust outlet, said control system comprising:

(a) a flow regulating device adapted to be positioned in the exhaust outlet and operable to selectively vary air flow outwardly therethrough;

(b) a sensing device having a sensing portion adapted to be positioned in the duct to sense therein a predetermined parameter related to the air flow rate through the duct, said flow sensing device further having an output portion;

(c) an adjustable set point comparator having an input portion coupled to said output portion of said sensing device, and an output adapted to generate an error signal;

(d) a proportional controller having an inlet coupled to said outlet of said comparator and further having an outlet;

(e) an integral controller having an inlet coupled to said outlet of said comparator and further having an ~~inlet;~~ OUTLET

(f) a summer having a first inlet coupled to said outlet of said proportional controller, a second inlet coupled to said outlet of said integral controller, and an outlet coupled to said flow regulating device; and

(g) a kicker connected between said outlet of said comparator and said integral controller to deactivate said integral controller when said error signal reaches a predetermined magnitude.--

--~~33~~ 19. (Amended) [The control system of Claim 32 wherein the compressor has] A control system for assuring a substantially constant minimum flow rate through a duct receiving air discharged from a compressor or the like having adjustable inlet guide vanes, the duct having a supply outlet connected to pneumatically-operated apparatus having a variable supply air demand, the duct further having an exhaust outlet, said control system comprising:

(a) a flow regulating device adapted to be positioned in the exhaust outlet and operable to selectively vary air flow outwardly therethrough;

(b) a sensing device having a sensing portion adapted to be positioned in the duct to sense therein a predetermined parameter related to the air flow rate through the duct, said sensing device further having an output portion;

(c) an adjustable set point comparator having an input portion coupled to said output portion of said sensing device, and an outlet adapted to generate an error signal;

(d) a proportional controller having an inlet coupled to said outlet of said comparator and further having an outlet;

(e) an integral controller having an inlet coupled to said outlet of said comparator and further having an ~~inlet~~ outlet; L.J.C.

(f) a summer having a first inlet coupled to said outlet of said proportional controller, a second inlet coupled to said outlet of said integral controller, and an outlet coupled to said flow regulating device; and [said control system further comprises]

(g) a guide vane position sensor and a function generator coupled in series between the inlet guide vanes and said input portion of said comparator.--

Change the dependency of Claims 10, 19, 20, 27, 38, 39, and 40 as follows:

In Claim 10, line 1, delete "6" and insert --8-- in place thereof, and delete "element" and insert --elements-- in place thereof.

In Claim 19, line 1, delete "16" and insert --17-- in place thereof.

In Claim 20, line 1, delete "16" and insert --17-- in place thereof.

In Claim 27, line 1, delete "~~21~~ 22" and insert --23-- in place thereof.

In Claim 38, line 1, delete "32" and insert --35-- in place thereof.

In Claim 39, line 1, delete "32" and insert --35-- in place thereof, and delete the word "flow".

In Claim 40, line 1, delete "32" and insert --35-- in place thereof.

REMARKS

Reconsideration of this application, as amended herein, is respectfully requested.

Claims 1-52 were originally presented for consideration in this application. Claims 41-52 have been withdrawn from consideration and are now the subject of a divisional application (serial number not yet received) filed pursuant to 37 CFR 1.60 on September 27, 1982. Accordingly, Claims 41-52 have been cancelled without prejudice in the instant application.

In his September 17, 1982 Office Action the Examiner rejected Claims 1 and 11 under 35 U.S.C. 102, and rejected Claims 1-3, 6, 7, 10-13, 16, 19-22, 27-29, 32, 37, 38, 39 and 40 under 35 U.S.C. 103. Claims 28, 31, 34 and 37 stand rejected under 35 U.S.C. 112 due to their recitation of the phrase "predetermined mode of operation". By the present amendment Claims 1-3, 6, 7, 11-13, 16, 21, 22, 28, 29, 31, 32, 34 and 37 have been cancelled without prejudice.

The Examiner has also indicated that Claims 8, 9, 17 and 18 would be allowable if rewritten in independent form, and that Claims 4, 5, 14, 15, 23-26, 30, 31 and 33-36 would also be allowable if rewritten in independent form and amended to overcome certain 35 U.S.C. 112 rejections. By the present amendment Claims 4, 8, 14, 17, 23, 30, 33 and 35 have been rewritten in independent form, and Claims 10, 19, 20, 27, 38, 39 and 40 have been amended to make them dependent from one of these rewritten, allowable claims. Claims 5, 9, 15, 18, 24, 25, 26, and 36, in their originally submitted form, already depend from one of these rewritten claims.

Relative to the remaining 35 U.S.C. 112 rejections, Claims 1-5 and 11-15 were rejected on such basis because of their recitation of "flow rate" as a sensed parameter. In response to this rejection, the phrase "means for sensing the gas flow rate through said duct means and generating an error signal having a magnitude indicative of the deviation between the sensed flow rate and a desired value thereof" in Claim 1 (now directly incorporated in rewritten Claim 4) has been changed to "means for sensing the value of a predetermined flow-related parameter within said duct

means and generating an error signal having a magnitude indicative of the deviation between the sensed value of said parameter and a desired value."

This modification is seen to clearly overcome the Examiner's 35 U.S.C. 112 rejection of Claim 4, and Claim 5 which depends therefrom. Specifically, this modification more particularly specifies that while it is the flow rate through the duct means which is ultimately controlled, it is a flow-related parameter (i.e. $\frac{P_t - P_s}{P_t}$) which is actually sensed within the duct means.

In contrast, Claim 11 (now directly incorporated in rewritten Claim 14) contained no recitation that anything whatever is "sensed" within the supply duct interconnected between the compressor and the pneumatically-powered apparatus. Thus, the Examiner's objection to the term "flow rate" as a sensed parameter in Claims 11-15 is incorrect. As rewritten, Claim 14 now recites "means, responsive to a variation in the flow rate of compressor discharge air through the supply duct, for producing an error signal . . ." Further, Claim 14 specifies control means for utilizing the error signal to modulate the surge bleed valve in a manner maintaining the air flow rate through the supply duct essentially constant.

Stated otherwise, while the control apparatus of Claim 14 controls the recited air flow rate, no specific mention is made of any "sensed" parameter used to effect such control. Accordingly, the term "flow rate" in rewritten Claim 14 is neither vague, ambiguous, nor a sensed control parameter and Claim 14, and Claim 15 which depends therefrom, are thus seen to be in a condition for allowance over the Examiner's 35 U.S.C. 112 rejection thereof.

Claims 21-40 were also rejected under 35 U.S.C. 112 on the basis that, in the Examiner's words, these claims "recite 'air flow' or 'flow' as the control parameter. While the intended meanings of these terms are not entirely clear, they appear to connote 'flow rate' and are deemed inaccurate for the same reasons as are Claims 1-5 and 11-15."

In response to this 35 U.S.C. 112 rejection, the following amendments have been made to rewritten independent Claims 23 and 35:

1. In Claim 23 the phrase "means for sensing the air flow through said main bleed duct means and generating an output signal indicative of the sensed flow rate" has been changed to "means for sensing a predetermined, flow-related parameter within said main bleed duct means and generating an output signal indicative of the sensed value of said parameter." Claim 23 now more clearly distinguishes between what is ultimately controlled (the air flow rate through the main bleed duct means) and what is actually sensed (a flow-related parameter with such duct means, such as the disclosed $\frac{P_t - P_s}{P_t}$). This amendment of Claim 23 is seen to clearly place such claim, and Claims 24-27 which depend therefrom, in a condition for allowance over the Examiner's 35 U.S.C. 112 rejection thereof.

2. In Claims 33 and 35 the phase "a flow sensing device having a sensing portion adapted to be positioned in the duct" has been changed to "a sensing device having a sensing portion adapted to be positioned in the duct to sense therein a predetermined parameter related to the air flow rate through the duct." This modification is seen to more clearly indicate that a flow-related parameter is actually sensed - not the actual flow rate.

Accordingly, Claims 33 and 35, and Claims 36 and 38-40 which depend from Claim 35, are now seen to be allowable over the Examiner's 35 U.S.C. 112 rejection thereof.

Rewritten Claim 30 does not specify the <u>sensing</u> of either "flow rate" or "flow" within the duct means. Accordingly, Claim 30 is seen to be allowable over the Examiner's 35 U.S.C. 112 rejection without amendment for the reasons set forth above relative to rewritten Claim 14.

In summary, all of the claims rejected by the Examiner in his September 17, 1982 Office Action have been cancelled without prejudice. All of the claims which he indicated would be allowable if rewritten in independent form have either been rewritten in independent form or depend from one of such rewritten claims. Appropriate amendments have been made to clearly overcome the 35 U.S.C. 112 rejections of certain of the claims. Additionally, two amendments have been made to the specification to correct minor typographical errors therein.

In view of the amendments made herein, and the foregoing remarks, all of the claims remaining in this application are seen to be allowable and such action is respectfully requested.

The Examiner has noted that the patents submitted with Applicants' May 27, 1981 Disclosure Statement have been noted, but will not be cited or fully considered because of, in the Examiner's words, "applicants' failure to provide an appropriate 'explanation of the relevance of <u>each</u> listed item' as required by 37 CFR 1.98(a)." Set forth below, <u>in a manner specifically authorized by M.P.E.P. 609,</u> is a "concise explanation of the relevance of each listed item "

SERIAL NUMBER | FILING DATE | FIRST NAMED APPLICANT | ATTORNEY DOCKET NO.

EXAMINER

ART UNIT | PAPER NUMBER

6

DATE MAILED:

This is a communication from the examiner in charge of your application.

COMMISSIONER OF PATENTS AND TRADEMARKS

1. ☐ THIS IS AN ATTACHMENT TO THE NOTICE OF ALLOWANCE AND BASE ISSUE FEE DUE, PTOL 85.

2. ☒ All the claims being allowable, PROSECUTION ON THE MERITS IS CLOSED in this application. If not attached hereto, a Notice of Allowance or other appropriate communication will be sent in due course.

A. ☐ Note the attached PTO-152, Notice of Informality, which indicates that the declaration (or oath) is deficient and that a substitute is required. The substitute declaration (or oath) MUST BE SUBMITTED WITHIN THE THREE MONTH STATUTORY PERIOD FOR PAYMENT OF THE BASE ISSUE FEE IN THE "NOTICE OF ALLOWANCE AND BASE ISSUE FEE DUE" (PTOL-85), preferably with and attached to the base issue fee. Note that the statute does not permit extension of the three month period set for payment of the base issue fee. Failure to timely file the substitute declaration (or oath) will result in ABANDONMENT of the application. The transmittal letter accompanying the declaration (or oath) should indicate the following in the upper right hand corner:

Issue Batch Number:
Date of the Notice of Allowance:
Serial Number:

B. ☐ Formal drawings are now required and MUST BE SUBMITTED WITHIN THE THREE MONTH STATUTORY PERIOD SET FOR PAYMENT OF THE BASE ISSUE FEE IN THE "NOTICE OF ALLOWANCE AND BASE ISSUE FEE DUE" (PTOL-85). Note that the statute does not permit extension of the three month period set to pay the base issue fee. Failure to timely submit the drawings will result in ABANDONMENT of the application. The drawings should be submitted as a separate paper with a transmittal letter which is addressed to the Official Draftsman and which indicates the following in the upper right hand corner:

Issue Batch Number:
Date of the Notice of Allowance:
Serial Number:

C. ☒ The claims are allowed in view of:

a. ☒ Applicant's communication filed 10/27/82

b. ☐ The interview summarized on the attached EXAMINER INTERVIEW SUMMARY RECORD, PTOL-413.

c. ☐ The Examiner's Amendment, attached. Should the changes and/or additions be unacceptable to applicant, an appropriate amendment may be proposed as provided by 37 CFR 1.312. To ensure consideration of such an amendment, it MUST be submitted before, or with, payment of the Base Issue Fee.

d. ☐ An Examiner's Amendment which will follow in due course.

D. ☐ The allowed claims are ________

3. ☐ Note the attached Examiners Statement of Reasons for Allowance. Any comments considered necessary by applicant regarding the statement of reasons for allowance must be submitted no later than the payment of the Base Issue Fee, preferably with it, to avoid processing delays. Such submissions should be clearly labeled, "Comments on Statement of Reasons for Allowance".

4. ☐ Note attached NOTICE OF REFERENCES CITED, PTO-892, which is part of this communication. The listed references are considered to be pertinent to the claimed invention, but the claims are deemed to be patentable thereover.

5. ☒ Note attached LIST OF ART CITED BY APPLICANT, PTO-1449, which is part of this communication and serves as an acknowledgment of receipt of applicant's prior art statement. The references which were considered have been initialed on the form by the examiner, and the claims are deemed patentable thereover.

6. ☐ The drawings filed on ________ ☐ are acceptable as filed. ☐ are acceptable subject to correction as indicated on the attached Notice re Drawings, PTO-948. In order to avoid ABANDONMENT of this application, correction is required. Corrections can only be made in accordance with the instructions set forth in the attached letter "INFORMATION ON HOW TO EFFECT DRAWING CHANGES".

7. ☐ The ☐ proposed drawing correction and/or the ☐ proposed additional or substitute sheet(s) of drawings filed on ________ has (have) been approved by the examiner. Applicant is reminded that in order to avoid abandonment of this application, execution of the proposed changes or submission of additional or substitute drawings MUST be made in accordance with the instructions set forth in the letter "INFORMATION ON HOW TO EFFECT DRAWING CHANGES", attached to Paper No. ________.

8. ☐ The proposed drawing correction, filed ________ has been approved. However, the Patent and Trademark Office no longer makes drawing changes. It is now applicant's responsibility to ensure that the drawings are corrected. Corrections are required and MUST be effected in accordance with the instructions set forth on the attached letter "INFORMATION ON HOW TO EFFECT DRAWING CHANGES".

9. ☐ In order to avoid ABANDONMENT, the drawing informalities noted on the Notice re Drawing, PTO-948, attached to Paper No. ________, must now be corrected. Applicant is reminded that the corrections can only be made in accordance with the instructions set forth in the letter "INFORMATION ON HOW TO EFFECT DRAWING CHANGES" attached to the PTO-948.

10. ☐ Acknowledgment is made of the claim for priority under 35 U.S.C. 119. The certified copy has; ☐ been received. ☐ not been received. ☐ been filed in parent application, Serial No. ________ filed on ________

L. J. Casaregola

L. J. CASAREGOLA
EXAMINER
ART UNIT 343

HSB 401479